TOSP for the Hall B BoNuS Target

Sept 2005
Rev 0.4

1 Introduction

The purpose of this TOSP is to provide a written procedure for installing, commissioning and initial operation of the Hall B BoNuS target and gas system. It outlines the procedures necessary to operate it. A list of people who will be responsible for installing and performing the tests is given at the end of the document.

2 Description of the Target

"BoNuS" is the acronym for the Bound Nucleon Structure Collaboration. The main purpose of the group is to study neutron structure by scattering electrons from a moderate-pressure deuterium gas target and detecting a slow-moving recoil "spectator" proton in coincidence. This experiment will use a novel proton recoil detector (a Radial Time Projection Chamber - RTPC - with GEM readout) in the CLAS.

The BoNuS Target consists of a Kapton Tube, 6 mm diameter with 50-micron walls and is 270 mm long. The upstream end of the tube is fixed to an aluminum cylinder that provides for gas plumbing. Aluminum windows cap the upstream and downstream ends of the target. This target will be fixed to the central axis of the BoNuS RTPC detector [fig. 1] and the assembly will be placed within the field of the DVCS magnet, on axis with the beam in Hall B.

3 Target Gas System

The BoNuS target gas system is static, i.e. the system is purged and charged with the appropriate gas then is valved off at the appropriate pressure. There is no continuous flow through the target. The target will be operated with either ultra high purity deuterium or hydrogen at 7.5 atmospheres and at ambient temperature. These gases are flammable and care must be taken to mitigate the hazards involved with its use. Before flowing any of these gases an “inerting” gas (nitrogen) will be used to displace the air in the system. Nitrogen will also be used to purge the target gas system once the test or experiment is finished. After construction of the gas system a leak check using Snoop followed by a flammable gas leak detector will be performed.

The target gas system is shown in Fig. 2. Flow of all the gases is restricted by an adjustable needle valve that will be locked out once the correct minimum flow is metered. Stainless steel tubing is used throughout the whole gas system. Remote control

of the valves may be incorporated in future runs. There is a flammable gas detector in place, located on the cold ring of the CLAS Torus, where the target will be located. Sensing of flammable gas will result in closing of all solenoid valves in the system.

4 Hazards

4.1 Flammable Gas

(Ref. JLAB EH&S Manual, Ch. 6152 and Appendices 6152-T1, 6152-T4, 6152-R1 and 6152-R2 and the MSDSs for each gas).

The gases which will be used for the BoNuS target are hydrogen and deuterium which are both flammable. The flammable limits in air of hydrogen are between 4.0% and 75% by volume. It has low ignition energy and can be ignited by a spark or flame or may ignite spontaneously from a sudden release of gas. Deuterium is a stable isotope of hydrogen. The flammable limits in air are between 4.9% and 75% by volume and has similar ignition characteristics to hydrogen. Exposure to air could occur from improperly connecting the high-pressure gas bottle to the target gas system, by leaking or broken process piping or by rupturing of the target cell.

4.1.1 Target Gas Pad

One bottle each of hydrogen, deuterium and nitrogen will be piped into the BoNuS target gas system. In order to minimize the gas inventory in the hall, these bottles will be located outdoors on the Hall B target gas pad which sits behind the Counting House. All three gas lines will be equipped with flow limiting valves before the lines enter the Hall. These valves will be set to provide no more than 4 sl/m at 10 atm. to the target.

As hydrogen and deuterium are flammable there can be no smoking, open flames or any operation nearby which generates sparks or flames. There are already signs in place to warn of the potential dangers. Each bottle of hydrogen contains 300 scf. The Q value is:

$$Q_{\text{hydrogen, 1cyl}} = 300 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.0899 \text{ kg/m}^3 = 0.76 \text{ kg}$$

Each bottle of deuterium contains 300 scf and therefore the Q value is:

$$Q_{\text{deuterium, 1cyl}} = 300 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.180 \text{ kg/m}^3 * 0.5 = 0.76 \text{ kg}$$

There will also be one bottle each of hydrogen and deuterium on the gas pad for the cryotarget gas system bringing the total Q value of all flammable gases on the pad to 3.04 kg hydrogen equivalent. All of the cylinders will be connected to their respective gas systems. There will be no storage of gas on the pad. Using the flow chart for determining risk classification we see that the Hall B gas pad will remain at Risk Class I.

All the requirements for Risk Class 0 and 1 installations must be read and understood by all of the operators of the BoNuS target gas system (see Appendix I).

4.1.2 In Hall B

The target is on the Hall B beamline, installed inside the BoNuS RTPC and is surrounded by helium gas. This target is used in place of the Hall B cryo-target that operates with the same gases. When BoNuS is installed the entire cryo-target gas inventory is removed from the hall.

Once the gas lines enter the hall, the volume including the target amounts to approximately 0.7 ft^3. At 10 atmospheres the equivalent volume of gas will be 7 ft^3, therefore,

$$Q_{\text{hydrogen, hall}} = 7 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.0899 \text{ kg/m}^3 = 0.02 \text{ kg}$$

and

$$Q_{\text{deuterium, hall}} = 7 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.180 \text{ kg/m}^3 * 0.5 = 0.02 \text{ kg}$$

Since there will be only one gas at a time used in the target, the Q value in the hall for the BoNuS target is 0.02 kg hydrogen equivalent. The amount of flammable gas in the BoNuS target is certainly no greater than the amount used in the cryo-target. This fact along with the measures that are already in place to reduce the fire hazards keep the risk classification in the hall at 0.

All the requirements for Risk Class 0 installations must be read and understood by all of the operators of the BoNuS target gas system (see Appendix I).

4.2 High Pressure Gas Bottles

(Ref. JLAB EH&S Manual, Ch.6150 and the MSDSs for each gas.)

The gases used for the BoNuS target are in high-pressure (2000 psi) gas bottles. This confined high-pressure gas represents a tremendous amount of stored energy. Use appropriate label to identify each gas cylinder, vessel and piping with it’s contents. Tear off tags are available to identify bottles that are full, in-use and empty. Because the target gas bottles are located on the existing gas pad, no special storage requirements are necessary but make sure that the bottles are secured in an upright position by an approved stand.

Care must be exercised in transporting the bottles from the storage racks near the Hall B gas shed to the target gas pad (approx. 30 yds.). Use a gas cylinder hand truck with securing strap. Roll the cart slowly and try to avoid hitting the large gravel lying in top of the asphalt as it may cause the cart to tip. There is thick bed of gravel about 2 ft. wide between the end of the asphalt and the start of the raised gas pad. Do not try to roll the cart over this gravel. Use a ramp.

5 Procedures

There are some automatic, firmware driven, safety features in place that will over-ride any manual operations that could cause damage to the target, cross contamination of the target gases or release of flammable target gas into the hall.

- If HSV86BT61 or HSV86BT31 is open, then HSV86BT43, HSV86BT45 and HSV86BT51 will close. In addition, If HPI86BT44 < 1 psig then HSV86BT45 will close. These measures prevent the target from collapsing due to sub-atmospheric pressure.

- If HSV86BT4 is open then HSV86BT14 and HSV86BT24 will be closed to prevent cross contamination of gas bottles.

- If HSV86BT14 is open then HSV86BT4 and HSV86BT24 will be closed to prevent cross contamination of gas bottles.

- If HSV86BT24 is open then HSV86BT4 and HSV86BT14 will be closed to prevent cross contamination of gas bottles.

- If the flammable gas leak detector signals the presence of hydrogen or deuterium then all solenoid valves (SVs) will be closed.

5.1 Flushing the Air or Target Gas Out of the System

This procedure is used when there is air in the system upon initialization or for removing flammable target gas from the system. No other procedure should be run until air has been replaced with N2 in the system.

1. Close all SVs.

2. Open N2 bottle and set regulator, HPR86BT21 to 20 psig.

3. Open HSV86BT51, HSV86BT43, HSV86BT45 and HSV86BT41 to vent all gas in the target system out of the hall.

4. When HPI86BT44 is less than 3psig, close HSV86BT51, HSV86BT45 and HSV86BT43.

5. If HPI86BT1 and HPI86BT42 < 3 psig then open HSV86BT31, and HSV86BT61. HSV86BT41 should still be open.

6. Turn on pumps HRP86BT62 and HRP86BT32.

HRP86BT62 is turned on using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to run the pump.

a) Type the password—"SIG" then <ENTER>.
b) Press F4.
c) Click on the red word "STOP" located on the screen under the representation of Pump CVP (located at bottom left of screen).
d) Type "1" then <ENTER>. Pump will turn green and "STOP" changes to "RUN".

HRP86BT32 is turned on using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to run the pump.

e) Type the password—"SIG" then <ENTER>.
f) Press F5.
g) Click on the red word "STOP" located on the screen under the representation of Pump VPS.
h) Type "1" then <ENTER>. Pump will turn green and "STOP" changes to "RUN".

7. When PSHVT on the Saclay screen indicates < 5e-2 mbar close HSV86BT31 and HSV86BT61.

8. Check the rate of rise of the pressure on HPI86BT1, HPI86BT42 and HPI86BT44 to confirm that no leaks have developed. This rate shall be determined upon commissioning of the system.

9. Stop pumps HRP86BT62 and HRP86BT32.

HRP86BT62 is turned off using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to stop the pump.

a) Type the password—"SIG" then <ENTER>.
b) Press F4.
c) Click on the green word "RUN" located on the screen under the representation of Pump CVP (located at bottom left of screen).
d) Type "0" then <ENTER>. Pump will turn grey and "RUN" changes to "STOP".

HRP86BT32 is turned off using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to stop the pump.

e) Type the password—"SIG" then <ENTER>.
f) Press F5.
g) Click on the green word "RUN" located on the screen under the representation of Pump VPS.
h) Type "0" then <ENTER>. Pump will turn grey and "RUN" changes to "STOP".

10. Open HSV86BT24 and fill the Buffer tank until HPI86BT42 reads approx. 5psig then close HSV86BT24.

11. Open, HSV86BT43 and HSV86BT45.

12. Open HSV86BT24 and fill the Buffer tank and Target until HPI86BT42 reads approx. 15psig then close HSV86BT24.

13. Wait 1 hour.

14. Repeat steps 3 through 13 one time.

15. Close N2 bottle.

5.2 Filling the System with Target Gas, Recharging the Target Gas or Changing the Target Gas

After the air has been purged from the system, use this procedure to fill the target with the working gas.

1. Close all SVs.

2. Open the target gas bottle (H2 or D2 -- never both) and set appropriate regulator, HPR86BT1 (H2) or HPR86BT11 (D2) to 100 psig.

3. Open HSV86BT51, HSV86BT43, HSV86BT45 and HSV86BT41 to vent all gas in the target system out of the hall.

4. When HPI86BT44 is less than 3 psig, close HSV86BT51, HSV86BT45 and HSV86BT43.

5. If HPI86BT1 and HPI86BT42 < 3 psig then open HSV86BT31, and HSV86BT61. HSV86BT41 should still be open.

6. Turn on pumps HRP86BT62 and HRP86BT32.

   HRP86BT62 is turned on using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to run the pump.

   a) Type the password—"SIG" then <ENTER>.
   b) Press F4.
   c) Click on the red word "STOP" located on the screen under the representation of Pump CVP (located on bottom left of screen).
   d) Type "1" then <ENTER>. Pump will turn green and "STOP" changes to "RUN".

   HRP86BT32 is turned on using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to run the pump.

   e) Type the password—"SIG" then <ENTER>.
   f) Press F5.
   g) Click on the red word "STOP" located on the screen under the representation of Pump VPS.
   h) Type "1" then <ENTER>. Pump will turn green and "STOP" changes to "RUN".

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7. When PSHVT on the Saclay screen indicates < 5e-2 mbar close HSV86BT31 and HSV86BT61.

8. Stop pumps HRP86BT62 and HRP86BT32.

   HRP86BT62 is turned off using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to stop the pump.

   i) Type the password—"SIG" then <ENTER>.
   j) Press F4.
   k) Click on the green word "RUN" located on the screen under the representation of Pump CVP (located on bottom left of screen).
   l) Type "0" then <ENTER>. Pump will turn grey and "RUN" changes to "STOP".

HRP86BT32 is turned off using one of the Saclay Cryotarget control PCs located on the second level of the space frame and in the Hall B counting house. Use the following procedure to stop the pump.

m) Type the password—"SIG" then <ENTER>.
n) Press F5.
o) Click on the green word "RUN" located on the screen under the representation of Pump VPS.
p) Type "0" then <ENTER>. Pump will turn grey and "RUN" changes to "STOP".

9. Open HSV86BT4 (H2) or HSV86BT14 (D2). Pressurize the buffer tank to approx. 2 psig on HPI86BT42 then close HSV86BT4 or HSV86BT14.

10. Open HSV86BT43 and HSV86BT45.

11. If this is the first time you are using this gas then wait 1 hour and repeat steps 3 through 10 then skip to the next step. If you are recharging the same gas then go to next step.

12. Open HSV86BT4 or HSV86BT14 if not already open and pressurize buffer tank and target to 95.5psig then close HSV86BT4 or HSV86BT14 and HSV86BT41.

13. Close the target gas bottle.

5.4 Exchange of Gas Bottles

When connecting or disconnecting a bottle of hydrogen or deuterium you must use the bronze explosion proof wrench located near the gas bottles on the gas pad.

6 List of Authorized Personnel

The list of the presently authorized personnel for work on the BoNuS Target gas system is given in Table 1, together with their signatures. Other individuals must notify and receive permission from the contact person [Table 1] before adding their names to the list.

When the BoNuS Target is used during the test phase or the production phase of the experiment, one of the authorized personnel shall be on-call, and his/her contact information posted in the counting house. Furthermore at least one shift worker shall be trained to perform the tasks described in Section 5. This training shall include a familiarization with this TOSP and with the hazards involved in the operation of the

BoNuS Target. The BoNuS Target contact person shall keep a list of the trained BoNuS Target operators, together with their signatures.

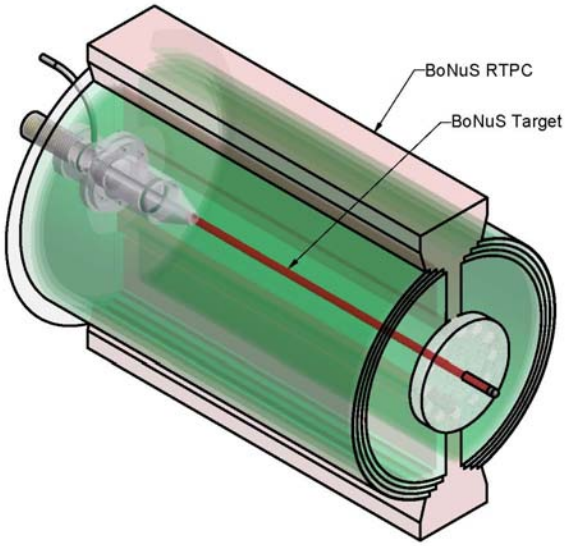

Figure 1 BoNuS Target

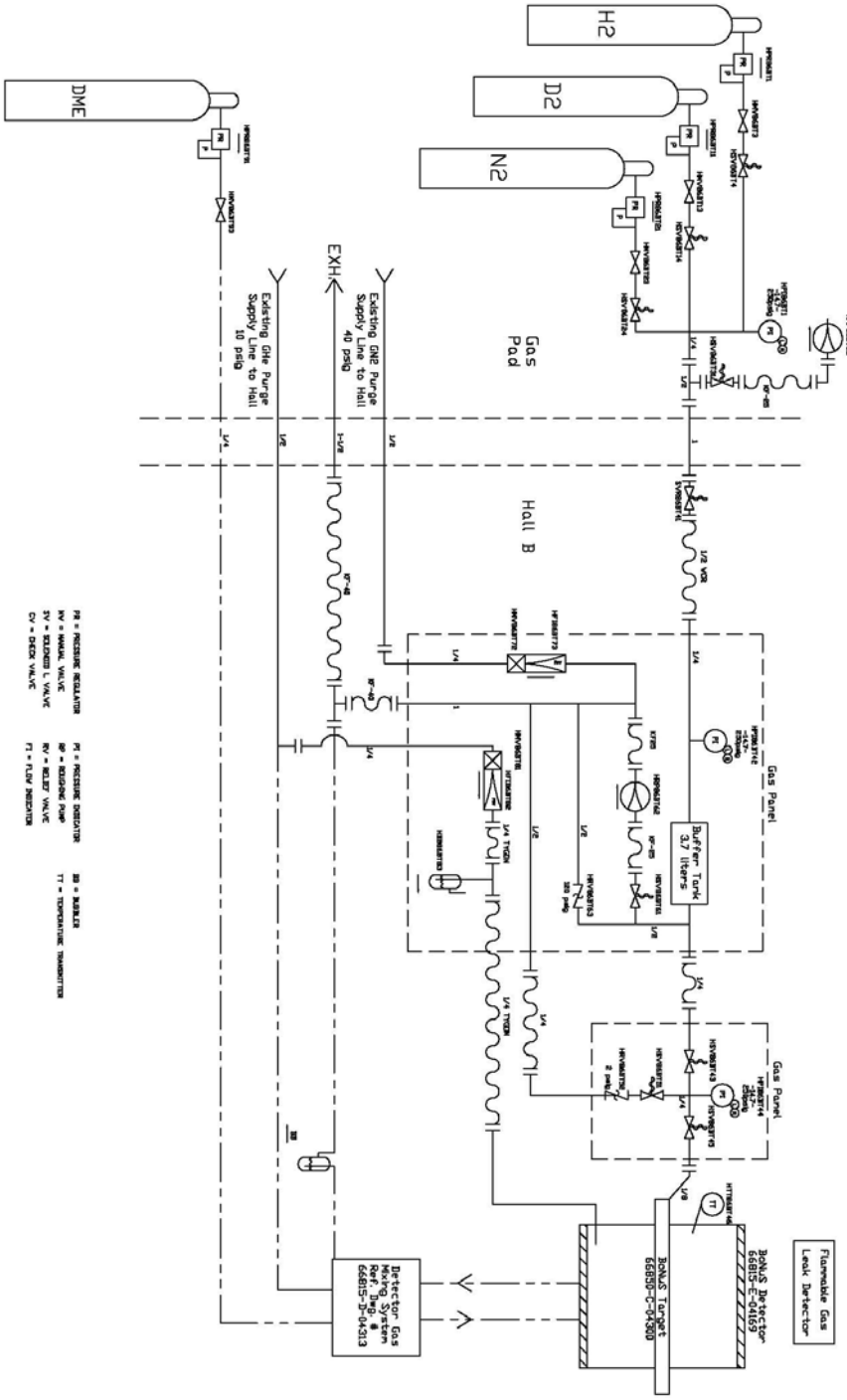

Figure 2 Target Gas System

Name	Dept.	Office Phone	Pager	e-mail	Comments
Signature					
S. Christo					
D. Kashy					
H. Fenker					
T. Keppel					
M. Christy					
S. Kuhn					

Table 1: BoNuS Target Gas System authorized Personnel.

Appendix I

Requirements for Flammable Gas Installations

A. Class 0 Installations:

1.The area shall be posted “Danger-Flammable Gases, No Ignition Sources” using standard signs available from the Jefferson Lab Safety Lab (in Building 35 or by contacting the Physics Division EH&S Staff). A list of responsible persons with their phone numbers shall also be posted.
2.Combustibles and ignition sources shall be minimized within 10 feet or three meters of gas handling equipment, piping or apparatus.
3.A pressure regulator appropriate for the gas and its environment shall be used.
4.An orifice, excess flow valve or other fixed means of limiting the flow to no higher than ten times the maximum operational flow rate shall be installed.
5.All gas cylinders shall be secured. Cylinders not in use shall be capped. Empty cylinders shall be removed at the earliest convenient date or on a predetermined, regular schedule coordinated with vendor delivery of new cylinders. See also Chapter **6150** *Compressed Gases*.
6.Enclosed volumes containing piping or equipment shall be incapable of becoming pressurized. For example, chest freezers shall not have latching doors. Electrical devices enclosing or enclosed within these volumes shall be listed for use in Class 1, Division 2 locations per NEC Article 500 or otherwise be documented and approved as non-sparking devices.
7.Leaks from experimental devices such as drift chambers shall be measured and documented prior to initial operation (with nonflammable gas, if possible). Leakage above seven liters/hour from any one chamber shall be mitigated. Recheck for leaks after major repairs or modifications, and at least every twelve months. Leakage exceeding 20% of the lower explosive limit at a distance over five centimeters from an identified “point” leak shall be repaired.
8.Ventilation above one air change per hour shall be maintained in areas using or storing flammable gas if normal operational flow rates are less than 5 Standard Cubic Liters Per Minute (SCLM). This ventilation may be accomplished by mechanical or natural ventilation. For natural ventilation a room vent with a minimum of ½ square foot of free area shall be provided per 1000 cubic feet of room volume. If normal operational flow rates are greater than or equal to 5 SCLM, supervised mechanical ventilation in accordance with Section 7-2.2.1(a) of NFPA 58 Liquefied Petroleum Gas Code, 2004 edition shall be provided (not applicable to outdoor Jefferson Lab storage).
9.Welding permits (Fire Hazard Work Permit) Reference *Appendix 6122-T1 Use of Fire Hazard Work Permits* shall not be issued for areas within 35 feet or ten meters of the equipment containing flammable gas unless approved in advance by the responsible Division/Section head or designee.

Class I Installations are subject to the following additional requirements:

10.The system, including vessels, chambers, supply and vent piping, and exhaust points shall be labeled “flammable gas.”

11.Piping requirements: Exceptions to this paragraph are permitted adjacent to experimental apparatus where needed for flexibility, electrical isolation, repairs or because of congestion. This exception is limited to within five meters of the normal operating position.

a. Piping and fittings shall be protected from mechanical damage.

b. Piping shall be rated for the expected temperature and pressure.

c. Supply piping shall be metallic.

d. Piping shall be supported in a substantial and workmanlike manner.

e. Piping shall not be installed inside cable trays with electrical conductors.

12.Joints shall be made by welding, brazing, pipe thread, or commercial fittings appropriately installed. Custom-made fittings required by detector design shall provide secure connections.

13.The entire piping system shall be pneumatically tested for leaks at approximately 0.9 times the relief pressure before operating the system. Any piping with relief valve settings above 150 PSIG shall be tested at 1.25 times the relief pressure.

14.Bubblers, flow meters, and other instruments shall be securely mounted and protected from possible breakage.

15.Provisions shall be made to purge the entire system with an inert gas. If vacuum pumps are used for this, they shall be listed for flammable gas service.

16.Pressure relief devices shall be provided to limit the pressure to the maximum working pressure in various parts of the system. In the case of low pressure equipment, dedicated bubblers may be used as relief devices. Common exhaust piping (where the flammable gas vent is shared with exhaust vents for other systems) shall not be used if equipment overpressure from any combination of devices sharing the exhaust could result due to built up back pressure.

17.Relief devices in flammable gas service with a capacity over two standard liters per minute shall be vented outdoors. The exhaust locations shall be chosen to minimize fire hazards and shall not be within 10 feet or three meters of an air intake. Vents shall be protected from clogging by debris, snow, or ice.

18.Flammable gas detectors shall be installed near equipment installations, mixing stations, and in storage sheds (the measures in this requirement are not necessary for outdoor storage applications):

a. A low level alarm no higher than 10% of the lower explosive limit (LEL) shall sound a local alarm and be used to initiate corrective action according to a plan included in the documentation of system operating procedures.

b. A high level alarm no higher than 25% of the lower explosive limit (LEL) shall summon the Newport News Fire Department through the Jefferson Lab fire alarm network. This high level alarm shall also automatically shut off the supply of flammable gas and turn off power to potential ignition sources within 10 feet or three meters of operative gas usage apparatus.

c. “Crash buttons” shall be provided to accomplish the shutdowns described above. These devices shall be conveniently located, and one shall be adjacent to the fire alarm panel, if present. Crash buttons should shut off all flammable gas

sources which could conceivably be confused by unfamiliar person in a state of panic. Crash buttons shall be labeled “Gas System and Experiment Power Shutdown.” They shall be located on the Building Evacuation Plan Maps.
d. Automatic restart of flammable gas systems and power sources shall not be allowed after a high level alarm. This restriction is intended to require a safety assessment of the situation. In case of an alarm follow the local emergency plan.

19.Visual indication of the actual use of flammable gas shall be provided at both the storage location and at the experimental apparatus. Such lights shall be controlled automatically and shall indicate actual “gas on” and “gas off” status in real time. Flammable gas alarm status shall be also be displayed at the locations of these warning lights.

20.Possible Oxygen Deficiency Hazards shall be addressed according to Chapter **6500** *Cryogenic and ODH Safety*. The hazard shall be considered for each building or room using or storing flammable or inert gas.

21.The following documentation shall be provided to the Experimental Equipment Review Committee (E2RC) and a copy kept at the system site.

a. A general description including the types of gases to be used.
b. An accurate piping and instrument diagram with symbols per ISA S5.1 (Instrument Society of America), including the normal set point of regulators.
c. An instrument and valve summary.
d. A plan view of the installation including the locations of flammable gas detector heads with their elevations marked.
e. Procedures for normal and abnormal operations including purging, start-up, gas bottle changes, mixing, leak detection, tests, alarms, shutdown, emergency situations, and ventilation.
f. Documentation and/or test results demonstrating the adequacy of the pressure-relief system.
g. A call list, including home telephone numbers and available pagers, of personnel familiar with the operation of the system.
h. A summary of leak-test measurements.

22.The Physics Division EH&S group shall be notified of actual gas start-up and system shutdown.

23.The Physics Division EH&S group shall be notified before using any types of gas not found in the stockroom, and a copy of the MSDS for the new gas shall be provided to both the Physics Division EH&S group and to the Jefferson Lab MSDS Coordinator. Reference Chapter **6610** *Chemical Hygiene* and *Appendix 6610-T1 Material Safety Data Sheets*.